Chapter 7

Food Utilization and Stability

Key Chapter Findings

- Biological contaminants in the food supply are highly sensitive to changing temperature and humidity, affecting food spoilage rates and human health.
- The adaptive capacity of food-system activities that influence food utilization and its stability is potentially very high but is also highly variable.
- Climate variability has already affected the stability of food utilization through extreme-weather events and their associated emergency responses.

Food *utilization* addresses the question "If food exists (i.e., is *available*), and you can get it *(access),* can you then make use of it?" This chapter defines food utilization, relates it to important components of the food system, and identifies areas where changes in climate have already and may in the future continue to influence food utilization. The chapter addresses the stability of food utilization, as well as adaptations for managing changing conditions.

What Is Food Utilization?

The principal measures of food utilization capture nutritional effects, focusing on an individual's ability to use the food that is both available and accessible. These outcomes are expressed in terms of malnutrition, which manifests as undernutrition or overnutrition (WHO 2003a). Shocks can also exacerbate causes of food insecurity outside the food system, including chronic poverty and disease (Irz et al. 2001, Thirtle et al. 2003, Ravallion et al. 2007, Schreiner 2012). Standards and regulations for processing and packaging are a key means to improve safety (and utilization potential) at multiple stages along the food system (Lee et al. 2012).

The term undernutrition captures the outcomes of inadequate caloric and/or nutrient intake (WFP 2012). These outcomes include stunting (short for one's age), wasting (thin for one's age), and micronutrient malnutrition (deficient in needed vitamins and minerals). Undernutrition is related to inadequate diet, care, feeding, and health practices, and/or compromised sanitation and hygiene. These factors can lead to infection, weight loss, nutrient depletion, and immunosuppression, which decreases the body's ability to fight infection and further reduces the absorption of nutrients, leading to a cycle of undernutrition and infection (Kau et al. 2011). For example, deficiency in vitamin A can lead to immunosuppression and blindness; iron deficiency can lead to anemia; and iodine deficiency can lead to goiter (Ramakrishnan and Semba 2008, Semba and Delange 2008, West and Darnton-Hill 2008).

In 1980, the prevalence of child stunting in the developing world was approximately 47% (de Onis et al. 2000). By 2010, the prevalence had decreased to 29.2% and is expected to decrease to 23.7% by 2020 (de Onis et al. 2012). In the developed world over the same time period, the prevalence of stunting has remained at about 6% (de Onis et al. 2012). While the developing world has seen an overall decrease in stunting and other measures of undernutrition over time, vast regional differences have been observed (Black et al. 2008). With the exception of North Africa, most regions of Africa have maintained a consistent level of child and maternal undernutrition (with stunting at 38%–40%). Asia and Latin America have seen the most dramatic decreases and are expected to reduce their stunting levels to 19% and 10%, respectively, by 2015 (de Onis et al. 2012).

Trends in overweight children have only recently been documented and are limited by available data, but they suggest that the prevalence of obesity since 1970 has increased for all developed countries.

Overnutrition refers to the consumption of too many calories or specific nutrients relative to the required levels for normal activities and/or growth and can manifest, for example, as an increase in weight or mineral poisoning. Overnutrition has been attributed to increased urbanization as well as changing lifestyles and diets (specifically, an increase in the consumption of processed foods, animal-source foods, fats, and sugars), and it is associated with diabetes, heart disease, and stroke (Kennedy et al. 2006, Popkin 2006, UN Standing Committee on Nutrition 2010, WHO 2003a). Although studies in the United States have shown conflicting results on the link between food insecurity and overnutrition (Dinour et al. 2007, Lohman et al. 2009, Martin and Ferris 2007), in developing countries undergoing a nutrition transition (e.g., Brazil, China, Guatemala, Indonesia, Vietnam, Russia, the Kyrgyz Republic), there has been a rise in the double burden of undernutrition and overnutrition occurring in the same populations and even in the same households (Doak et al. 2005, Kennedy et al. 2006).

Trends in overweight children have only recently been documented and are limited by available data, but they suggest that the prevalence of obesity since 1970 has increased for all developed countries and for a number of developing countries (Wang and Lobstein 2006). North America and Europe report the highest prevalence of obese and overweight children (as high as 30%, with the expectation that this figure could increase to 46%). Southeast Asia and much of Africa report the lowest prevalence of overweight children and the slowest rate of obesity (Wang and Lobstein, 2006). Some countries that have experienced rapid economic development are now coping with both childhood undernutrition and overnutrition, particularly among the lowest socioeconomic groups (Jones-Smith et al. 2011, Wang and Lobstein 2006).

In addition to these types of individual manifestations reflecting food utilization, there are societal elements as well. Individuals may place high value on locally produced food, culturally important food, or food that they themselves produce (Altieri and Toledo 2011, Rosset 2008). Alternatively, they may have limited knowledge regarding the preparation of unfamiliar food types. These issues of cultural appropriateness, individual values, and preparation skill may be particularly acute for women, who are often the household food preparers (Ibnouf 2009, Quisumbing et al. 1995). Changes in the geography of food production, and/or changes in trade patterns that may make some familiar foods less available or accessible and/or increase the availability or accessibility of unfamiliar foods, may alter utilization patterns.

7.1 Influences on Food Utilization and Stability

Climate has a number of potential and observed effects on contamination of the food supply, on the nutritional composition of food, and on a body's ability to assimilate the available nutrients, all of which influence food utilization and each of which is discussed below.

7.1.1 Food Safety

Climate change can affect food safety throughout various stages of the food supply chain (Jacxsens et al. 2010, Tirado et al. 2010). Food safety is a critical means by which changes in climate can affect the utilization of food by influencing vectors of food contamination and levels of toxins in food. Elongated supply chains expose food products to greater risk of potential contamination and make it harder to verify the quality of the products at various stages (Swinnen 2007), but also allow more diversity in consumption and more stability over time.

Vulnerability of transport infrastructure to extreme events (IPCC 2012) can affect utilization by hindering the movement of food from its place of production to consumers and increasing the likelihood of food contamination. Temperature increases have been associated with illness from Salmonella and Campylobacteria, which may be related to poor food storage and handling practices in the supply chain. In general, increased temperatures are known to cause an increase in diarrheal diseases (which can lead to malnutrition); bacterial foodborne diseases grow and reproduce faster at elevated temperatures (Bandyopadhyay et al. 2012, Tirado et al. 2010). For example, in one study in Peru, the incidence of diarrheal diseases increased by 8% for every 1 °C increase in temperature (Checkley et al. 2000). However, some viruses, such as noroviruses, which can be transferred when contaminated foods or liquids are ingested, show an increased prevalence in children in winter, particularly during times of low immunity in the population and the emergence of novel genetic variants (Velázquez et al. 2004, Levy et al. 2009, Cook et al. 1990, Tirado et al. 2010). A decrease in infection rates could therefore result from warmer winters. These health challenges are not confined to low-income countries. For instance, a study in England found that for every 1 °C increase in temperature, there was a 5% increase in the number of reports of Campylobacter enteritis, up to a threshold of 14 °C (Tam et al. 2006).

Fungal infections of crops, particularly of the genus *Aspergillus,* can have severe effects on human health and nutrition whether consumed directly or through the milk produced by livestock who have themselves consumed infected crops (Wagacha and Muthomi 2008, Williams et al. 2004). Aflatoxin, a potent mycotoxin, is produced by *Aspergillus* and is known to lead to cancer, as well as developmental and immune-system suppression; in severe cases it can lead to death (Williams et al. 2004, Wu et al. 2011). Fungal contamination is a result of pre-harvest practices; timing of harvest; handling of produce; moisture levels during harvest, storage, transportation, and processing; and insect damage (Wagacha and Muthomi 2008, Cotty and Jaime-Garcia 2007, Miraglia et al. 2009, Tirado et al. 2010). Climate change can affect crop contamination, which can increase during the warm and dry periods of crop development, as some mycotoxin-producing fungi grow best in warmer temperatures (Paterson and Lima 2011, Sanders et al. 1984, Schmitt and Hurburgh 1989). Crops such as maize and peanuts, staple foods for large populations, can be affected, though effects vary depending on the region and temperature and rainfall changes within the region (Paterson and Lima 2011). In low-income countries, the problem of mycotoxin contamination in food and feed due to lack of refrigeration or climate-controlled containers is becoming more widely recognized (Groopman et al. 2008). A synergistic effect between mycotoxin exposure and some critical diseases in Africa, such as malaria, kwashiorkor, and HIV/AIDS, is also suggested by several studies (Wagacha and Muthomi 2008, Williams et al. 2010).

Aquatic and fishery food sources are important, both as sources of protein and for income generation (FAO 2009b). The warming of the upper ocean and uneven changes in the nutrient density of the water (Barange and Perry 2009) can promote harmful algal blooms, which produce toxins that contaminate seafood and can cause illnesses such as paralytic shellfish poisoning, diarrhetic shellfish poisoning, and neurotoxic shellfish poisoning in humans. In addition, climate-related fluctuations in sea salinity can cause a more rapid uptake of toxic chemicals by fungi, bacteria, mollusks, and crustaceans and an increased uptake and bioaccumulation by crustaceans and mollusks (Marques et al. 2010).

7.1.2 Nutrition

The body's utilization of macro- and micronutrients, required vitamins and minerals, and related dietary compounds is a critical component of food utilization. Micronutrients are nutrients that are needed in relatively small quantities in the diet. They play important roles in sight, immune function, and cellular signaling, among other biological processes.

Climatic factors can potentially affect the availability and use of micronutrients in several ways, which can lead to micronutrient deficiencies (Loladze 2002). One study found that the concentration of iron and zinc found in staple grains and legumes is reduced under elevated atmospheric carbon dioxide, a driver of climate change (Myers et al. 2014). Another study found that protein (a macronutrient) content in milk declined with increased temperature and humidity above threshold values (Bahashwan 2014, Nardone et al. 2010, Renna et al. 2010). Other nutritional effects are more uncertain under changing climate (Renna et al. 2010). Evidence of climatic effects on nutrient content in fruits and vegetables, for example, remains limited (Burke and Lobell 2010).

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The nutritional quality of a number of staple foods is diminished by elevated atmospheric CO_2 concentrations (Ceccarelli et al. 2010). Under increasingly high concentrations of atmospheric CO_2, nitrogen concentration, a proxy for protein content, appears to diminish by 10%–14% in the edible portions of wheat, rice, barley, and potato, and by 1.5 % in soybeans (Müller et al. 2014, Taub and Wang 2008). Mineral and micronutrient concentrations in the edible portions of crops are also likely to diminish under elevated CO_2 concentrations (IPCC 2014). The overall nutritional quality of many important food sources is therefore diminished in a changing climate.

One result of the historical focus on additional calories as the primary means of achieving food security has been the increased production of high-yielding rice, maize, and wheat crops. The result has been a reduction in micronutrient (iron and zinc) concentrations, as well as protein content, in the overall mix of crops produced. This has resulted in lower nutrient availability for portions of the population who rely on cereals as their main food source (DeFries et al. 2015).

7.1.3 Environmental Enteropathy

Climate also affects utilization through changes in nutrition-*sensitive* factors. For example, a review of nutrition-related interventions undertaken in 36 countries demonstrated that food-utilization outcomes are shaped not only by nutritional inputs, but also by factors such as disease burden; women's empowerment; and water, sanitation, and hygiene (Bhutta et al. 2008).

These wider climate-sensitive factors affect utilization through environmental enteropathy (EE), a subclinical condition associated with intestinal infections, altered gut morphology, chronic inflammation, and increased gut permeability, and in turn, increased entrance of bacteria into the body and poor nutrient absorption, leading to undernutrition (McKay et al. 2010). Increasing waterborne diarrheal diseases, including cholera, that are among the causes of EE are associated with extreme-weather events, particularly in areas with poor sanitation (Confalonieri et al. 2007). EE itself is associated with stunting and wasting (Campbell et al. 2003). The climate change to EE to diminished food utilization chain of events has not yet been studied in an end-to-end fashion; however, the relationships established between climate variables and EE causes, and EE's association with diminished food-utilization capacity, imply that climate change may influence the prevalence of EE and, ultimately, undernutrition.

7.1.4 Storing, Processing, and Packaging Food

Food storage, processing, and packaging often include both capital-intensive and labor-intensive systems coexisting in the same region, with each system having different vulnerabilities to weather and climate (Lee et al. 2012). Poor storage is a major cause of food loss, and proper packaging prevents damage and contamination. In developing countries, there are significant post-harvest losses due to financial and structural limitations in harvest techniques, inadequate or poorly managed storage and transport infrastructures, and climatic conditions favorable to food spoilage (FAO 2013a). Higher temperatures can also prolong damage by pests (e.g., rodents, insects) after harvest, absent appropriate storage methods (Magan et al. 2003, De Lima 1979). Post-harvest losses vary by region and industrial process, as losses are dependent on the specific conditions and local situation in a given country or region. For example, lack of appropriate storage facilities for food crops can lead to pest infestations or mold growth that render the crops inedible (Parfitt et al. 2010). As temperatures rise, post-harvest losses may increase in regions without appropriate processing and storage facilities.

Food-safety issues increase when the agricultural product-processing sector lags behind broader agriculture growth, which has been the case in many food-insecure countries (Byerlee et al. 2005). Modern packaging and storage facilities are currently deficient in most developing countries (IAASTD 2008). Higher temperatures can affect food packaging by degrading the plastics, rubber, and wood materials over time (Andrady et al. 2003). In low-income countries, lack of cold storage on farms and in wholesale and retail outlets can result in loss to pests and rotting (Vermeulen and Campbell et al. 2012). In east and southern Africa, for example, grain is often stored outside or in open-air sheds and may be affected by weather shocks (Stathers et al. 2013). Unusually wet weather in the dry season can significantly harm grain stored for future use (Nukenine 2010).

7.1.5 Consumption and Disposing of Food

The final stage in the food system is consuming food, which involves buying, preparing, and eating food at the individual or household level (Ericksen 2008). Food consumption has increased over the past 50 years by 400 kcal per person per day, with dramatic decreases in the prevalence of hunger in many areas (Kearney 2010). Large increases in the consumption of vegetable oils (199%), meat (119%), and sugar (199%) in low-income countries between 1963 and 2003 reveal significant expansion of food availability across all income brackets (Alexandratos and Bruinsma 2012). At the same time, declines were seen in the consumption of pulses and roots over these four decades (Kearney 2010). These changes have been driven largely by technological and socioeconomic factors, and how climate change will further affect these changes is uncertain.

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The marked rise in available food energy observed globally has been accompanied by changes in dietary composition that have affected overall food demand (IAASTD 2008). The extra calories come from cheaper foodstuffs of vegetable origin in both developed and developing countries (Kearney 2010, Smil 2000). Income growth, urbanization, and increasing demands on people's time that might otherwise be used for food preparation together result in larger proportions of the diet being composed of prepared foods that are high in fats, sugar, and salt, resulting in adverse health consequences (Popkin 1999). Increasing demand for meat and dairy from urban populations is further straining the agricultural system (IAASTD 2008).

Estimates suggest that 30%–50% of total food production is lost globally as waste (Gustavsson et al. 2011). Similar levels of waste are observed in developed and developing nations, with differing causes in each case. In developing nations, the absence of adequate food-system infrastructure is a primary cause of food waste (Godfray and Beddington et al. 2010). This issue was discussed in the "Food Availability and Stability" chapter of this report. Waste in retail, food service, and at home accounts for the majority of food waste in developed regions (Parfitt et al. 2010).

7.2 Adaptation for Food Utilization and Stability

Diminished food utilization or utilization stability can result when the food system fails to adapt to changes in climate. Vulnerabilities are particularly apparent during extreme-weather events when time is critical (Ericksen 2008, Hillbruner and Moloney 2012, Lautze et al. 2012). A number of options exist for adaptation to better enable food utilization and stability that may be appropriate under differing circumstances.

A variety of techniques exist to reduce post-harvest losses resulting from food spoilage and include varietal selection, biological control, storage structures, chemical treatments, botanical and inert dusts, and improved handling and processing (Affognona et al. 2015). Additional monitoring for food pathogens and contaminants will be adaptive under higher temperatures and humidities as a means of managing food safety (Gregory et al. 2009). Prerefrigeration methods of food storage (e.g., drying, salting, pickling) may be used effectively in a changing climate (Shepherd 2012, Gitonga et al. 2013). Reduced intervals between harvest and storage can diminish the faster rates of spoilage that occur under higher temperatures and humidity. Cold storage is another possible adaptation, though costs increase with additional refrigeration (James and James 2010). High levels of food processing can reduce the need for cold storage (Young 2013) and may consequently represent a means of adaptation that ameliorates refrigeration costs.

Disruptions in delivery systems may become more probable in a changing climate (Stecke and Kumar 2009), with implications for "just-in-time" logistical supply systems, which attempt to match the rate of food production to the rate of food consumption to avoid the need for the maintenance of large storage areas. Greater supply-chain redundancy may be one productive approach (CDP 2015, Altay and Ramirez 2010) and becomes more economically feasible under more-rapid levels of change (Global Commerce Initiative 2009).

As the nutritional value of food diminishes under elevated atmospheric CO_2, adaptations might include greater cultivation of protein-rich crops (Linnemann and Dijkstra 2002), the inclusion of animal protein sources (Golden et al. 2011), or cultivation protein sources that are less familiar for some, such as insects (Shockley and Dossey 2014), particularly in cases where inadequate protein limits food-security status. Such adaptations might require the economic means to purchase animal-protein sources, farmland for additional leguminous crops, or a willingness to eat unfamiliar protein sources. Feedbacks from this adaptation might include potential changes to other components of food security, such as overall global food demand in cases where grains are used as feed (Kearney 2010, West et al. 2014).

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Changing production geography may make familiar foods less available or accessible in some cases, and unfamiliar or less familiar foods may take their place. This can result in reduced utilization, perhaps transient, due to lack of familiarity with preparation methods for the new food types (Axelson 1986). Reduced utilization may disproportionately affect women (Ibnouf 2009, Quisumbing et al. 1995). The greater the change in familiar foods as a consequence of changes in climate, the greater the adaptation required, whether that entails paying more for familiar foods that are grown at a greater distance, purchasing the less-familiar foods and learning how to prepare them in a culturally appropriate way, or a combination of multiple adaptive habits.

Increased disease prevalence and distribution in a changing climate may lead to increased use of veterinary drugs or pesticides, bringing with it the possibility of higher residue concentrations in food and possible effects on consumption choices (FAO 2008a, Tirado et al. 2010, Cooper et al. 2014). This illustrates that where adaptation is possible, it may have consequences of its own.

7.3 Measuring Food Utilization and Stability

Food-utilization outcomes, expressed by anthropometric, clinical, or biochemical indicators of nutritional status, are usually measured by health and nutrition surveys carried out every 4–6 years, and thus do not always reflect seasonal and annual situations (Grace et al. 2014, Shively et al. 2015). Both poverty and undernourishment indicators refer to habitual consumption, usually over the span of a year (or the average of a 3-year period), and can help to identify issues where utilization of food is impaired.

Undernourishment is intended to measure chronic or habitual insufficiency of dietary energy, rather than short-term consumption fluctuations. For children under the age of 5, habitual insufficiencies can be measured by estimating the proportion of children with a low height-for-age (stunting). Short-term fluctuations can be measured for both adults and children by estimating the proportion of individuals with a low weight-for-height or low mid-upper-arm circumference as a measure of wasting (Gorstein et al. 1994) and can be used in combination with body mass index to estimate food insecurity. Overnourishment is measured by body mass index (James et al. 2004, Mathers et al. 2009).

Seasonal or other short-term changes in consumption (stability) are common in agrarian settings where the timing of production and employment affect food-security status and is difficult to measure, as it requires high-frequency (i.e., monthly or seasonal) data that is highly spatially variable (de Haen et al. 2011). Few countries have systems in place for such a purpose. Where seasonality is an important component of food utilization, survey data are generally poor sources of information (de Haen et al. 2011). Despite the relevance to climate change, there is virtually no widely used source of data on seasonal variation of consumption or other factors related to food utilization and its stability at a household or community level (Barrett 2010).

7.4 Conclusions and the Future

Food safety and utilization have strong relationships to temperature and humidity; changes in these parameters are therefore likely to result in greater food-safety challenges, including the potential to alter human health outcomes from foodborne illness (D'Souza et al. 2004). Influences on food utilization—food safety and nutrition; food processing, packaging, and storage; and food consumption and disposal—are likely to be increasingly challenged by changing climatic conditions.

Fruit and vegetable crops harvested with higher pulp temperatures require more energy for proper cooling (Moretti et al. 2010). Higher temperatures and humidity generally cause increased mycotoxin accumulation (Magan et al. 2003, Fandohan et al. 2003, Rossi et al. 2001, Coakley et al. 1999). While exceeding a fungus's biophysical temperature threshold will reduce mycotoxin-related food spoilage, fungal populations can adapt to local conditions (Coakley et al. 1999). The need for refrigeration and dehumidification to reduce fungal growth can lead to strains on electricity grids (James and James 2010) and comes at increased cost. Managing food-security outcomes requires a comprehensive understanding of the interactive effects of adaptive choices throughout the food system and indicates that single-point adaptation itself may not, in many cases, be a panacea for managing systemic food-security outcomes (Ludwig 2011).

More-frequent food pathogen and contaminant monitoring may also be indicated in a changing climate (Gregory et al. 2009). At this time, monitoring surveys tend to be large-scale and prone to miss regional granularity food-safety threats, which may be addressed, at least in part, by more frequent monitoring of food from or in regions undergoing more rapid environmental change or adaptation (Lake et al. 2012).

The rapid expansion of food transport to supply supermarket-type retailing structures lengthens the period of time between harvest and consumption, potentially exposing food to conditions that may result in higher rates of contamination (Ercsey-Ravasz et al. 2012). As a consequence, some food products may require updated processing, packaging, and storage or may require protective packaging for the first time (Parfitt et al. 2010). Industry addresses food processing, packaging, and storage requirements to meet legal trade and food safety specifications (CDP 2015, WHO 2003b), but such data are not often available for scientific analysis. Documented relationships between food safety and climate variables that are expected to change, however, imply an increased need for adaptation in food processing, packaging, and storage (Parfitt et al. 2010).

The rapid expansion of food transport to supply supermarket-type retailing structures lengthens the period of time between harvest and consumption, potentially exposing food to conditions that may result in higher rates of contamination.

Food-storage techniques such as drying, salting, and pickling are effective under increased temperatures and humidity, and may be used more widely or more rapidly after harvest to reduce the risk of food spoilage under higher temperatures (Affognona et al. 2015).

More-highly processed foods may be consumed more frequently in the future, helping to ameliorate both potential food-safety concerns and higher energy costs, though introducing other variables into the human health equation (Monteiro et al. 2011).

7.4.1 Food Utilization in the Context of Shared Socioeconomic Pathways (SSPs)

The influence of climate change on food utilization and its stability depends on how key elements of the food system respond to changes in climate under differing socioeconomic trajectories. Many parts of the food system are not considered by the SSPs or by existing modeling frameworks; Figure 7.1 reflects informed judgments of the authors on the relative risks to food safety and environmental enteropathy from climate change for different development pathways, based on inferences from the available literature on the subjects.

Shared Socioeconomic Pathway	Food Safety		Health Status	
	P	W	P	W
SSP1	Medium/Low Risk	Low Risk	Medium/Low Risk	Low Risk
SSP2	Medium Risk	Medium/Low Risk	Medium Risk	Low Risk
SSP3	High Risk	Low Risk	Medium Risk	Low Risk
SSP4	Medium Risk	Medium/Low Risk	Medium Risk	Low Risk
SSP5	Medium/Low Risk	Low Risk	Medium/Low Risk	Low Risk

(P: poorer nations, W: wealthier nations)

Key
Low Risk
Medium/Low Risk
Medium Risk
High Risk
Very High Risk

Figure 7.1 Relative risks to food utilization for different SSPs. *The risks to food utilization would be lowest under the economic scenarios described in SSP1 and SSP5, with poorer nations at higher risk across all food utilization categories for all SSPs. Shading represents higher or lower risks for each SSP from climate change. Risks reflect the informed judgment of the authors of this report, based on the available literature.*

Food Safety

Across all SSPs, in wealthy countries where effective controls exist, food safety is not likely to be significantly affected by climate change. Poor countries, however, could experience significant variability in food safety across the SSPs. Economic growth and technology transfer under SSP1 is likely to ameliorate the effects of changing temperatures on food safety in poorer countries. Similarly, high rates of economic growth under SSP5 might produce income increases and increase expectations of improved food safety.

Under SSP2, technology transfer and economic growth would be somewhat lower than under SSP1, but the globalized trade regime might compel investment in or transfer of food-safety technologies due to international certification requirements, limiting significant food-safety impacts. Another possibility is that more-globalized trade could facilitate the movement of unsafe food into wealthy countries at higher rates than occur today. Under SSP3, more-modest economic growth would limit additional education and infrastructure developments that might otherwise contribute to improved food safety. Technology transfer, which is expected to be low under this scenario, would not fill that gap. In SSP4, poor countries would experience similar challenges as under SSP3, given low rates of economic growth and low technology transfer. However, the globalized trade regime might compel the international transfer of food-safety technologies to meet international certification requirements, which would address food-safety challenges in these countries. If not, food exports from these countries could result in more unsafe food consumption in importing countries.

Environmental Enteropathy

Given existing infrastructure and levels of public health, wealthy countries are likely to maintain low rates of EE under all SSPs in a changing climate. Rates of economic growth are expected to be high, and environmental quality would be expected to be high or improve in poor countries under SSPs 1 and 5, expanding their ability to manage climate change and respond quickly to disasters that would otherwise allow cholera and similar conditions to spread, contributing to EE.

Environmental quality is expected to deteriorate under SSPs 2, 3, and 4. For these SSPs, changing patterns of climate-related disasters are more likely to result in higher rates of EE-based diseases in places with little capacity to address them. Under SSP4, high levels of intracountry inequality could produce highly variable outcomes within a country, with the wealthy largely insulated from EE-related stressors and the poor experiencing increasing exposure.